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ABOUT THE DENTINE PENETRATION CAPABILITIES OF CHLORINE AND OZONE
[Über die Dentindurchdringungsfähigkeit von Chlor und Ozon]

by

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IV. Experimental Part

The solution to the following questions is intended:

1. What physical assumptions are given by capillary attraction? What diffusion proportions are present with chlorine gas and what are those for ozone-oxygen mixtures?

2. How deep can Dentine be penetrated by color solutions?

   a. Teeth in the jaw (gangrene).

   b. Freshly extracted teeth.

   c. Dried out teeth from collections.

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3. How deep do chlorine and ozone penetrate Dentine? Does it penetrate the intact coat of cement?

a. Measurements with side drillings.

b. Experiments with teeth soaked in indicator solution.

c. Pressure experiments, teeth with and without cement.

4. How great is the partial pressure with ozone anesthetization (open chamber of pulpa in middle third of root)?

1. Some model experiments with glass capillaries should clarify under several conditions the proportions of capillary rise and diffusion to serve as basis for future tests.

In the case of dry teeth, the dentine system equals a porous ceramic filter. Since each dentine canal (dk) is closed on its extreme sides and the interior is filled with air, special conditions must be present (anastomosis, wick action due to organic residues) to let the capillary attraction become effective. The air can escape through those side connections and penetration of the fluid can be accomplished. It was determined by respective changes of the test arrangements how big the capillary effect is on capillary tubes closed on one side.

a) Capillary (diameter 0.2 mm) open on both ends, immersed 2 mm deep into a watery and alcoholic solution of Methyl violet. Rise: approximately 4.1 cm.

b) Capillary with one side smelted, conditions as above. Rise: approximately 0.5 cm.

c) Capillary with silk thread as wick, both ends open. Slow rise to approximately 5.7 cm. Clear water or clear alcohol will be sucked to approximately 4-7 mm above the last visible color trace.

d) Capillary with silk thread wick conditions as before, one side smelted. Rise: approximately 4.8 cm. Pure solution agent in upper part.

e) Capillary on one side closed with 3 mm high water column. The water will not be expulsed but acts as a lock like smelting the capillary.

f) Capillary filled completely with water, then immersed into dye, 2 mm deep. Slow color diffusion in several days. It does not matter if the capillary is open on both ends or one end is closed.

g) Capillary filled completely with serum. Conditions as under f; slower and more ample diffusion as with waterfilled capillaries.

The tests show that capillaries closed on one side have practically no attraction; it is equal to the compressibility of the enclosed air within. A considerable rise is to be expected even by capillaries closed on one side as soon as a wick is inserted into the capillary since the wick acts as a "capillary within a capillary" giving the air contained within a chance to move sideways and downward. The diffusion tests lead to the following observations.

Capillaries of 5 cm length and 0.1-0.4 mm in diameter have been filled with water, liquid chicken albumen, blood serum, and carcass fat (Benzidine added as an indicator); some of the tubes have been closed on one side by paraffin. The capillaries were put into a glass container filled with pure chlorine gas. The progress of discoloring was observed by hourly taking measurements, extended to four days with the tubes containing the fat. The ozone-oxygen mixture in the test tubes was renewed 3 times daily (pressure: 0.4 atü *)while the rest of the gas was always left within.

*) 1 atü = 2,116.2 lbs/foot^2

Both gases show a progressive diffusion into the mediums used. This occurs considerably slower with the fat capillaries. Chlorine gas proved to be somewhat superior over the $O_2 \cdot O_3$ in regards to the diffusion speed. The diffusion is accelerated in thinner capillaries. Some diffusion phases of the fat capillaries are shown in Figure # 5. The diffusion values of the capillaries (0.4 mm dia) filled with serum and fat, in chlorine and oxygen-ozone atmosphere, are shown in Figure # 6. When the tests were repeated with capillaries immersed in chlorine gas pressurized to 0.2-0.3 atü, the diffusion occurred faster; in principle, there were no differences to be determined.

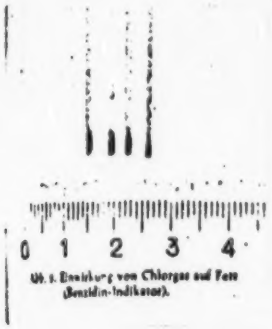

Figure # 5
Reaction of chlorine gas and fat (Benzidine indicator)

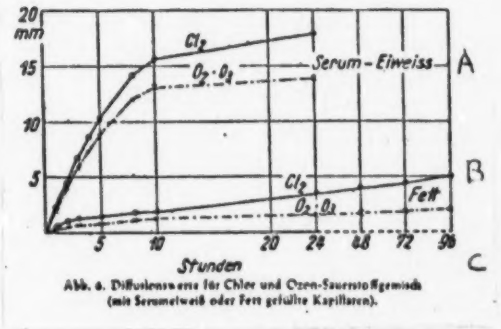

Figure # 6
Diffusion values for chlorine and ozone-oxygen mixture (with serum albumen or fat filled capillaries)

Key: A. serum albumen
B. fat
C. hours

2. Teeth still in the jaw but ready for extraction have been prepared up to the apex and filled with alcoholic solutions of brilliant cresyl blue, methyl violet, and methyl blue. Using the filter paper method, the particles in these color solutions proved sufficiently small. A paper tip soaked with color solution was inserted, a small soaked cotton pellet was put into the pulpa chamber and closed with cement. Twenty-four to 48 hours later, the teeth have been extracted, immediately divided in half and ground. Xylol has been used for wetting to prevent washout of the penetrated color. Freshly extracted and older teeth from collections which have been stored for one or two days in a humid room at 37°C have been treated similarly.

The penetration depth of the color solutions showed distinctive differences according to the kind of treatment. It was the least on the teeth treated in the jaw, the greatest on the teeth from the collections, a result which we expected. In no case, however, did the color solution penetrate the cement, the most extraneous border noted was always the Tomes' grain layer or the terminations of dk. A frequent result was the unequal color penetration as shown in Figure # 7 . However, colored regions have been contrasted by more or less small bands of uncolored dentine. Deviations from the average penetration depth were present in each series (see Figure # 7, second tooth from the right, lower column; dry teeth). These deviations are caused by the different individual characteristics of the teeth material as well as the different age of the teeth. It resulted in the fact that the younger teeth color better and more evenly than older ones, on the average.

Figure # 7
Teeth treated with color solution, freshly extracted (f) and dry teeth. The color diffusion is remarkably greater with the latter ones.

It is known that the lesser or missing penetration through obliteration of the dk on the root canal entrance is caused by secondary dentine layers. The increasing sclerosis of the dentine during advancing age is expressed clearly by reduced coloring of the hard teeth substance. One seldom goes wrong, in principle, by carrying over the results gained with color solutions on teeth of determined origin and characteristics to the penetration depth of gaslike reagents although qualitative differences could result.

3a. Penetration depth of Chlorine and Ozone; measurements with side drills

Freshly extracted teeth or those from our collection have been drilled on the sides with fine Rose drills; openings of different depths, located beneath and opposite each other have been produced to be able to check the gas penetration on the thinner or thicker dentine layers. The drill hole bottoms were then polished

and planed with a counter sunk milling-cutter. The root canal was prepared with a drill, Beutelrock 3. The last third of the root was surrounded with a thick cap of hard paraffin whose gas consistency is greater than that of a cement cover or cement amalgam. The apical foramen was left open on part of the teeth to secure a continued follow-up of the gas. Gas escaping there was diverted by means of a plastic tube. The test teeth have been checked before -- as well as in all later cases -- by pressurized, induced air for complete absence of side canals and open cement rarefications.

The tooth tested for the time being has been fastened by paraffin in such a way in the middle of a drilled glass panel measuring 33 x 60 cm, that the crown part projects on one side, the root on the other. This arrangement served as protection against possible traces of gas escaping through the connection of the cannula or the conical screw of the Cytozon apparatus which could falsify the results. The cannula has been implanted into the middle of the root canal. Thus, the returning $O_2 \cdot O_3$ mixture was syphoned from the canal and directed into the open.

The individual drill holes have been covered with paraffin paper except for one. This one has been covered with Benzidine reactive paper (Benzidin II, Merck, alcoholic saturated solution) and the gas was injected into the root canal on the other side of the glass panel. Discoloring time and intensity of the indicator paper have been determined and evaluated hole by hole. Since the holes had been drilled at different depths, it was possible, using the above method, to pinpoint the exact hole, out of so many holes, where no gas penetration occurred anymore.

The teeth have been cut now and ground by a diamond disc to 0.2 mm as shown in Figure # 8, and the depth distance from the root canal of each individual drill hole was measured using an ocular micrometer (Figure # 9).

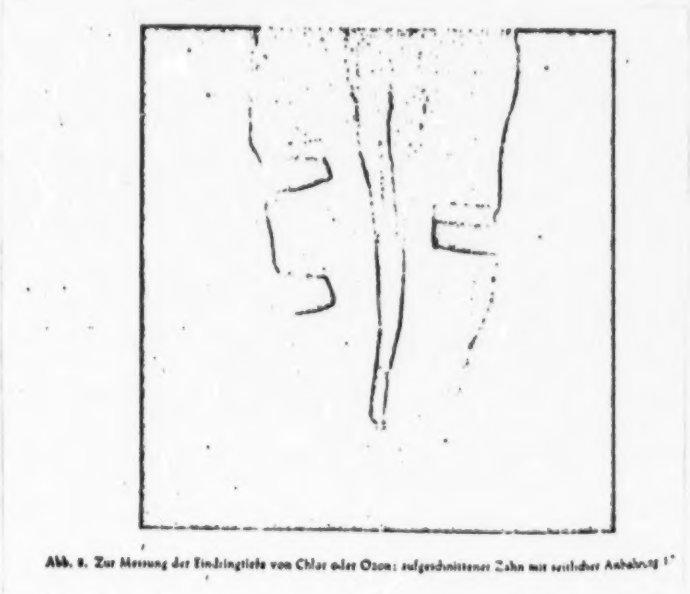

Abb. 8. Zur Messung der Eindringtiefe von Chlor oder Ozon: aufgeschnittener Zahn mit seitlicher Anbohrung

Figure # 8: To measure penetration depth of chlorine and ozone; cut tooth with side drills

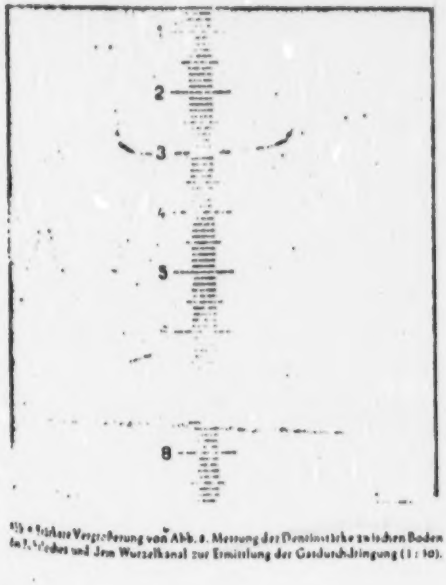

Figure # 9: Emphasized enlargement of Figure # 8. Measurement of dentine thickness between drill hole depth and root canal to determine gas penetration (1:30)

The lower limit of dentine penetration capability (partial sclerogenous dentine or partial obliteration by secondary dentine) for ozone (pressure 0.8 atü, open cavum) was found to be 0.48 mm, the upper limit 1.93 mm, using thinner teeth tapered to the branches of dk. The lower chlorine limit has the same value as ozone. The upper limit, with few exceptions, is always on the branches of dk. Here the chlorine gas has a pressure of about 250 torr (= approximately 25 cm mercury). The values communicated are the average results of more than 150 measurements. The cement penetration was negative; it could not be determined closely for individual layers because of minor cement thickness. No gas penetration occurred on superficially drilled cement.

The gas penetration was significantly greater on dry teeth than on freshly extracted ones which, in general, gave only half the values. In comparison to the tests made with liquid media, the gases penetrated dentine deeper than the liquids. Gas penetration timely supercedes the latter as well.

A change in testing techniques, namely to fill the drill holes with a half-liquid indicator and to observe its reaction under 10x magnification, failed. The indicator liquid does penetrate the dentine partially and produces an unclear, diffuse discoloring.

3b. Teeth Saturated with indicator solution

Freshly extracted and older teeth have been prepared as said above and the root tips closed with a paraffin cap. These teeth have before been immersed for 4 days in 50 ccm saturated alcoholic benzidine solution to which 4 drops of anilin and 2 drops of ice vinegar had been added. Chlorine gas with about 200 torr pressure was injected into the obturated tooth for 5 minutes. The gas at first discolors the indicator a very strong, deep blue which then turns rust brown. The teeth, when cut open, show a reaction of the indicator up to the Tomes' grain layer and even farther into the final branches of the dk (Figure # 10). Diminishing the time of gassing from 1 minute to 30 seconds brought out very clearly the difference between using fresh teeth and teeth which had been dried out beforehand. The latter almost always were colored up towards the end of the dk, while the former were colored only half way through the root dentine thickness in the same period of gassing time as the chlorine therapy. Discoloring of the fiber cement could not be observed in any case.

Abb. 10. Nach Durchtränkung mit Benzidin-Indikator chlorbegaster Zahn. Ausläufer der Dentinkanälchen [illegible] in der Tomes'schen Körnerschicht. Farbreaktion nur im Bereich des Dentins. Das Zement (unten) zeigt keine [illegible] (Schliff 1 : 400).

Figure # 10: Chlorine gassed tooth after saturation with benzidine indicator. Extensions of the dentine canals end ...[Not legible]... in the Tomes' grain layer. Color reaction only within dentine range. Cement below does not show ...[Not legible]... (Grinding 1:400)

Using collection teeth, we attained equally good results with ozone-oxygen mixture as with chlorine gas. Cytozon gas was directed into the root canal with a pressure of 0.7 atü, the pulpa chamber open. Here the pressure within the system of the dentine canals is considerably less than in those teeth with closed pulpa chambers, using chlorine gas. The results using freshly extracted teeth dropped considerably. The reaction of the indicator was only 1/3 to 1/2 as big as with chlorine.

3c. Pressure tests on teeth with and without cement

In compliance with the Weigele tests, we immersed teeth in an indicator solution after the lower third of the root was completely closed with paraffin. We used Iodine/Starch-Iodide solution as a test solution as well as the more sensitive Ortho-Toluidin, or Benzidine solution. Chlorine gas was injected under a pressure of 0.4 atü for 2 to 3 days into the canal. A minor-graded discoloring of the indicator is traceable to gas diffusion due to unpreventable leakage at the entrance point into the cannula. A sudden color change of the whole indicator never occurred. The teeth had been carefully proven for airtightness beforehand. We had the same results with teeth imbedded in indicator soaked gelatine or prepared agar.

Teeth with well proportioned, feasibly round roots were robbed of their cement by careful grinding, whereby many dk have been opened more or less from the outside. Now chlorine gas was pressed into the teeth with varying pressures (up to 0.3 atü). A different rapid and strong discoloring of the indicator could be observed. It took sometimes up to 4 hours with fresh teeth until a reaction of the indicator could be observed. Here the organic ingredients of the dentine or of the Tomes' fibers are coagulated; gas penetration

occurs then only indirectly by reaction of the dissolved chlorions upon the indicator.

4. Partial pressure with Ozone gassing

Since the ozone-oxygen mixture is applied with the open pulpa chamber in opposition to chlorine gassing, the pressure upon the dk is only part of the total pressure with which the gas escapes the cannula. The amount of this partial pressure was determined as follows with the individual fine valve adjustments of the cytozon apparatus.

A strong corner tooth with a spacious pulpa chamber and a straight root canal was prepared up to the apex. A hole of 0.8 mm dia was drilled in the middle third part of the root and a capillary manometer was cemented into it. The capillary had a diameter of 0.15 mm at its point of exit from the root canal. Besides at the capillary entrance point, the whole root received a thick cover of hard paraffin. The pressure increase is observed on the manometer when the cannula is introduced into the pulpa chamber. When the needle is positioned close to the front of the capillary, the mercury rises to a maximum point. When the needle is brought forward to the lower third of the root canal, the mercury declines steeply to zero.

When the cannula is positioned close to the front of the capillary manometer opening, it is measured:

Adjusted manometer position	8 (= 0.8 atü)	: about	33 torr[1]
	10	: about	54 torr
	12	: about	81 torr
	15	: about	132 torr

[1] The mercury fraction inside the capillary is included in these values.

About 15,000 dk equal the capillary diameter of the manometer taking as a basis 75,000 dk/mm^2 of the dentine surface. The real pressure for the single dk is therefore very small; in addition, the condition must exist that the dk is located in front of the cannula opening.

The demand to move the cannula about repeatedly can be practically derived from the results using cytozonan in cases of gangrene. The desired gas infiltration of the non-obliterated dk is only to be expected if the needle tip does not rest on the same spot during gassing.

V. Evaluation of the Test Results

Did the tests answer the question: do the gases chlorine and ozone penetrate the hard teeth substances faster and further than liquid medication? It was proven in cut and ground preparations that the liquids can penetrate the end branches of the dk under the most favorable conditions. However, the following conditions must be satisfied: the dk must be passable for liquids up to the last branches and not blocked by calcium deposits, substrates containing albumen or fat, etc. Alcohol solutions diffuse faster than watery ones in which diffusion can be increased by addition of a moistening agent (fat alcohol sulfonate). Solution agents of the hydrocarbon and chlorinated hydrocarbon line act similar to alcoholic solutions; however, their results are more favorable.

The diffusion is directly related to the size of the molecules of the substance dissolved. However, even with small molecules, it is dependent upon the dk being passable, that means that a conversion

of the solutions into the primary cement does not take place. There is no influence on the primary cement. Cells containing cement will be penetrated by color solutions where capillary connections to the dk exist. Dry teeth penetration capability is mostly the same for gases and liquids. Freshly extracted teeth, especially those with numerous Tomes' fibers present, show very clearly differences in penetration capabilities, of which gas has the best.

Those teeth saturated with an indicator solution show visible differences between fresh and older teeth when injected with chlorine gas under a pressure of approximately 200 torr and changing injection times. The reaction attained from ozone gassing equaled 1/3 to 1/2 of the chlorine values. No evidence, in any case, could be found of the cement being penetrated by the gases. The lesser reaction of ozone gassing is attributed to the completely different pressure conditions which are given at open pulpa chambers. The objection is fully valid during testing that any indicator reaction can only occur in the saturation zone; however, this is dependent upon the diffusion capability of the indicator liquid.

Nevertheless, the other tests do not show that the gases can penetrate the hard teeth substances beyond the cement. They advance only as much as they find free roads. No diffusion takes place where the path is blocked by hard substances. Organic media are influenced chemically by sufficient gas supply, this reaction is desired for gangrene therapy. The diffusion speed corresponds to the diminution of contractibility of the solute gas within the organic medium. The very reactive gases consume themselves very rapidly. Influencing fat containing matter even with chlorine gas is to be attained only slowly.

From the results of our tests, we can not verify that gases penetrate a tooth filterlike, i.e. like a pencil. Cement coating represents a non-penetrable resistance to the gas. A reaction of the indicator to the usage of chlorine occurs more or less quickly when the first is removed from older teeth. The test does not succeed in the same manner with freshly extracted teeth but only after prolonged test continuance. It is assumed that organic residues are first coagulated by chlorine and are more difficult to penetrate thereafter. The reaction speed depends upon the state of decay of the Tomes' fibers.

Weigele's point of view holds that there is no need to flush any dk rendered non-penetrable by calcium barriers with chlorine gas since there is nothing to disinfect within these tubes. Certainly he is not wrong with this opinion if he thinks about completely sclerosed dentine. The possibility exists, however, that the dk are only blocked by secondary dentine near the root canal, but the part of the tube situated beyond is infected by germs which infiltrated from microbe-containing granulation tissue through resorbed cement or through capillary rifts present close to the apex and are nourished from there. Therefore, deposits of bacteria which are not influenced would still exist which, sooner or later, could generate reinfections.

A complete obliteration of the canal lumen by denticles and several calcium deposits are very often found in the last third of strongly bent roots of older teeth whereas necrotic germ-carrying matter is still lodged within the part of the canal near the apex. Even in such cases, we consider it inopportune to expect a gas to

penetrate this block of hard substances which has but a few canals without significant quantitative diminution. The infinitesimal quantities of gas which might possibly surmount the calcium block are not sufficient, according to our expectations, to effectively destroy the germs. The disinfection of canals which are completely closed on one spot remains at least problematic. Even after a once successful germ extinction, all necrotic and not carefully filled cavities could become a source of bacterial dissemination after a certain latency and harbor the peril of relapse. To leave them at that is also irresponsible from the viewpoint of doctrinal teaching of focal infections.

For therapy, the recommendation to frequently move the cannula within the root canal during gassing could be derived from the ozone test results. The intended gas infiltration of all open dk can only be accomplished if the needle tip does not always rest on the same spot.

In a former essay, we already pointed out that no miracle results could be expected from gas-like medications. The principles of gangrene therapy (cleaning, preparation, correct filling of the canal and as much of the branches as possible) will not be shaken by them. The application of gas-like media is recommended for biological and technical disinfectory reasons. However, the biology of the gases chlorine and ozone, and their effects upon periapical processes, still needs intensive research. Thanks to Fisch and his assistants, investigations of the ozone treatment rests already upon a well founded base of histopathological works. Weigele also endeavors to broaden the foundations about the biological reactions

of chlorine gas and, furthermore, to find methods to facilitate the use of chlorine in social practice. How far those can be brought in accordarce with the basic demands of gangrene treatment must be awaited.

VI. Synopsis

The penetration depth of different color solutions into the dentine substance of teeth still in the jaw, freshly extracted and older teeth from collections has been compared with that of chlorine and ozone gas. Non-organic impedients within the dk as well as undamaged cement are hereby not penetrated; organic residues are influenced depending upon the chemical characteristics of the gases. How much self-blocking caused by albumen metabolism of fresh Tomes' fibers took place, could not safely be determined. Fat-containing substrates are penetrated slowly in vitro by chlorine, albumen significantly quicker. The reaction of cytozon gas is similar, however, the reactions deviate timewise.

The penetration depths ascertained by drill and indicator tests vary from tooth to tooth but can be brought into a distinctive proportion with a sufficient number of tests. It was determined, that gas diffuses until it reaches the cement in older teeth and penetration depth is greater for gases than liquids in freshly extracted teeth.

The partial pressure of ozone in the middle of the root third was determined to be approximately 30 torr with the manometer valve in the usual therapeutic position, if the gas cannula lies

right in front of the measured capillary; beyond, the values decline sharply. It is therefore advisable to move the needle about often during application in order to reach a greater efficiency of the ozone-oxygen mixture.

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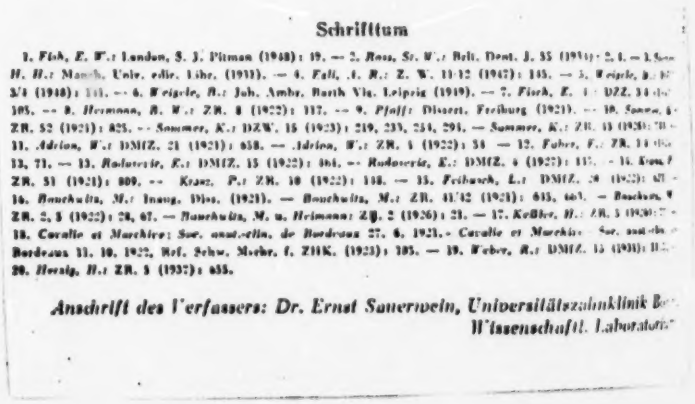
Bibliography



Schrifttum

1. *Fish, E. W.:* London, S. J. Pitman (1948): 19. — 2. *Ross, Sr. W.:* Brit. Dent. J. 55 (1934): 2, 4. — 3. *Sco... H. H.:* Manch. Univ. educ. Libr. (1933). — 4. *Fall, A. R.:* Z. W. 11/12 (1947): 145. — 5. *Weigele, R.:* 3/4 (1948): 111. — 6. *Weigele, R.:* Joh. Ambr. Barth Vlg. Leipzig (1949). — 7. *Fisch, E.:* DZZ. 3... 105. — 8. *Hermann, R. W.:* ZR. 8 (1922): 117. — 9. *Pfaff:* Dissert. Freiburg (1921). — 10. *Sauer,* ZR. 52 (1923): 825. — *Sommer, K.:* DZW. 15 (1923): 219, 233, 254, 291. — *Sommer, K.:* ZR. 13 (1924): 71. — 11. *Adrion, W.:* DMfZ. 21 (1921): 658. — *Adrion, W.:* ZR. 1 (1922): 58. — 12. *Faber, F.:* ZR. 14 (... 13, 71. — 13. *Radoseric, E.:* DMfZ. 15 (1922): 864. — *Radoseric, E.:* DMfZ. 4 (1922): 117. — 14. *Kraus:* ZR. 51 (1921): 809. — *Kraus, P.:* ZR. 10 (1922): 118. — 15. *Fribusch, L.:* DMfZ. 20 (1923): 67. — 16. *Bouchuits, M.:* Inaug. Diss. (1921). — *Bouchuits, M.:* ZR. 41/42 (1921): 645, 661. — *Bouchuits, M.:* ZR. 2, 3 (1922): 28, 67. — *Bouchuits, M. u. Heimann:* ZB. 2 (1926): 21. — 17. *Kolber, H.:* ZR. 5 (1930): 7. — 18. *Cavalie et Marchive:* Soc. anat.-clin. de Bordeaux 27. 6. 1921. — *Cavalie et Marchive:* Soc. anat.-cli... Bordeaux 11. 10. 1922, Ref. Schw. Mschr. f. ZHK. (1923): 185. — 19. *Weber, R.:* DMfZ. 15 (1931): 1... 20. *Herzig, H.:* ZR. 3 (1932): 655.

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